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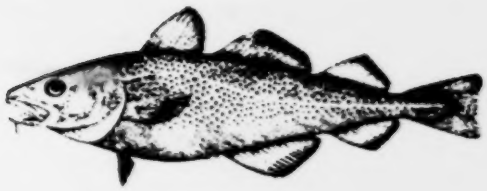
Newfoundland and Labrador Region
Canadian Science Advisory Secretariat
Science Advisory Report 2010/019

STOCK ASSESSMENT OF NORTHERN (2J3KL) COD IN 2010



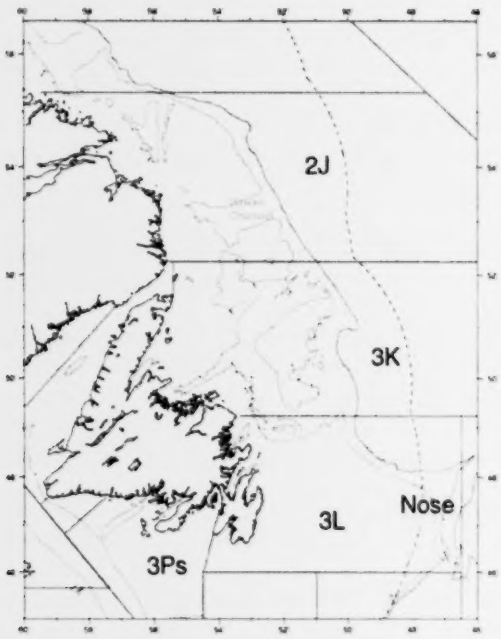


Figure 1: Stock area of northern (2J3KL) cod. The dashed line indicates Canada's 200 nautical mile Exclusive Economic Zone (EEZ).

Context :

The biomass (of ages 3 and older) of the northern cod (Gadus morhua) stock off southern Labrador and eastern Newfoundland (NAFO Divisions 2J3KL; Fig. 1) was about 3 million t in the early 1960s. Fishing intensity increased greatly in the 1960s as non-Canadian fleets exploited dense offshore over-wintering aggregations. The stock collapsed to about 0.5 million t by the late 1970s. After extension of jurisdiction in 1977, the stock recovered partially to just over 1 million t in the mid-1980s, but it declined again during the late 1980s and collapsed to an extremely low level by the early to mid-1990s. A moratorium on directed commercial fishing was declared in 1992.

Historically, many cod migrated from over-wintering areas offshore to feeding areas inshore, where they were exploited by the traditional inshore fixed-gear fishery. By the mid-1990s it was apparent that these offshore populations were barely detectable. At the same time, it was recognized that there were aggregations of cod in the inshore in Div. 3L and southern Div. 3K. These inshore populations appeared to be more productive during the 1990s than populations in the offshore. A small fishery directed at these inshore populations was introduced in 1998. Catch rates declined and the directed commercial fishery was closed in 2003. A food/recreational fishery, which had been open for several years, was also closed. Catches during 2003-2005 were limited mainly to bycatch in the winter flounder (blackback) fishery.

A directed stewardship fishery and recreational fisheries were re-opened in the inshore in 2006 and continued in 2007-09. This stock is assessed annually, however, no target goals or timelines have been identified by management against which current status and trends can be compared for advice purposes.

June 2010

Canada

The present assessment is the result of a request for science advice from the Fisheries and Aquaculture Management (FAM) Branch (Newfoundland and Labrador Region). The main objectives were to evaluate the status of the stock and to provide scientific advice concerning conservation outcomes related to various fishery management options.

The current evaluation of the stock was conducted through a regional assessment process (RAP). The meeting was held 15-19 and 22-24 March 2010 in St. John's (NL). Participants included DFO Scientists, fisheries managers, and officials from provincial governments, non-government organizations, fishing industry members, and academia.

SUMMARY

Catch

- Total catch in 2009 is uncertain. Accurate catch information is needed to evaluate the impact of future fishery removals on stock growth.
- Reported landings in 2009 were 3,098 t. This included 2,832 t in the stewardship fishery, 216 t in the sentinel surveys, and 50 t taken as by-catch, but excludes recreational fishery removals.
- There are no direct estimates of recreational landings for 2009. However, analysis of tag returns suggests that removals from recreational fisheries during 2009 could be 64% of the stewardship fishery removals.

Offshore

- Based on a cohort analysis of the autumn DFO research vessel (RV) trawl survey, total **biomass** has increased (23% per year) since 2004. **Spawning stock biomass** (**SSB**) increased (83% per year) from 2004 to 2008, but the 2009 value was similar to 2008.
- Total **mortality** in the offshore was extremely high during 1996-2003 and was a major impediment to stock recovery. Total **mortality** has declined substantially since 2003 and this has been an important factor in the recent increase in total **biomass** and **SSB**.
- The 2003 and 2004 year-classes are weaker than those produced in 1998-2002 and have now entered the **SSB**; consequently, the recent rate of stock growth is unlikely to continue in the short term. Subsequent year classes (2005 and 2006) are estimated at about the 1993-2007 average.
- The average survey **SSB** estimate in the offshore over the last 3 years is 10% of the average during the 1980's and is concentrated adjacent to the 3K/3L border.
- The number of young fish (ages 2 and 3) in the offshore survey in the 1990s and 2000s has been consistently much lower than during the 1980s. Further stock growth will require an improvement in recruitment which has not been observed to date.
- Offshore tagging and telemetry indicate that a substantial portion of cod from an offshore aggregation migrated to the inshore of 3KL during the summer. Exploitation of these offshore cod in the inshore was low, estimated at 6% in 2008 and 2% in 2009.

Inshore

- Sentinel catch rates suggest that **exploitable biomass** in 2009 was near the 1995-2009 average, but lower than in 2008 for the northern, central and southern inshore regions.

- In the inshore northern area catch rates are lower than those in the central area suggesting lower **exploitable biomass** in the northern area. Fisheries in this area depend on seasonal immigration of fish, possibly from offshore regions, including 2J where offshore biomass remains low. Therefore, it is recommended that removals from this area be minimized.

- During 2007-2009, mean exploitation rates from tagging studies were low and ranged from 3-10% among inshore central and southern areas.

- In the inshore central area, catches depend on resident inshore components and seasonal migrants from the offshore.

- Exploitable biomass in the central inshore area is likely to decrease further in 2010 even with no removals. The 2003 and 2004 year-classes are weaker than those produced in 2000 and 2002, and the 2002 year-class is moving out of the exploitable biomass. Therefore, if current levels of removals are maintained then exploitation rates in the central inshore area are expected to increase in 2010.

- In the inshore southern area, catches are partly dependent on seasonal immigration of fish from the offshore of 3KL, and from 3Ps where the stock is declining.

- The 2009 industry telephone survey showed most harvesters in 2J3KL felt that cod were more abundant during 2009 than in the 1980s.

Whole stock

- Although a specific limit reference point has not been established, the stock is clearly below any reasonable value. The application of the precautionary approach would require catches in 2010 to be at the lowest possible level. This would include no directed fishing and measures to reduce cod by-catch in other fisheries.

- Current levels of removals have resulted in low exploitation rates and probably have had little impact on recent stock dynamics. In general, the 2003-2005 year-classes are weaker than those from 1999-2002. Consequently, even with no fishing, the recent (2004-2008) high rate of growth in **SSB** is unlikely to continue in 2010. Current levels of removals will not greatly affect the rate of change in SSB in 2010.

INTRODUCTION

History of the Fishery

Catches of northern cod increased during the 1960s to a peak of over 800,000 t in 1968, declined steadily to a low of 140,000 t in 1978, increased to about 240,000 t through much of the 1980s, and then declined rapidly in the early 1990s in advance of a moratorium on directed fishing in 1992 (Fig. 2).

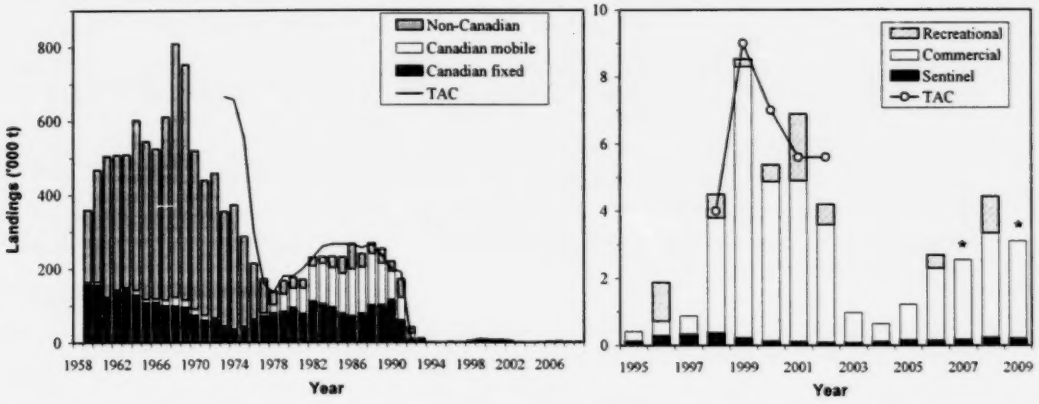


Figure 2: TACs and landings (thousands of tons) in 1959-2009. The right panel is expanded to show trends from 1995 onwards. Asterisk indicates that recreational catches in 2007 and 2009 are uncertain (see text).

Catches during 1993-1997 came from by-catches, food/recreational fisheries, and DFO-industry sentinel surveys that started in 1995. In addition, catches from 1998-2002 also came from a limited index/commercial inshore fishery restricted to fixed gear and small vessels (<65 ft). The directed commercial and recreational fisheries were closed in April 2003; most of the landings in 2003 came from an unusual mortality event in Smith Sound, Trinity Bay (Colbourne et al. 2003). During 2004 and 2005, substantial by-catches (>600 t) of cod were taken in the inshore, mostly in 3KL, in the winter flounder (blackback) fishery.

A stewardship fishery and a recreational fishery for cod were re-opened in 2006 and continued in 2007-2009. Commercial fishers were permitted an allowance of 3,000 lb of cod per license holder in 2006, 2,500 lb in 2007, 3,300 lb in 2008, and 3,750 lb in 2009. Total catch in 2009 is uncertain. Reported landings in 2009 were 3,098 t. This included 2,832 t in the stewardship fishery, 216 t in the sentinel surveys, and 50 t taken as by-catch, but excluded recreational removals. There are no direct estimates of recreational landings for 2009. However, analysis of tag returns suggests that removals from recreational fisheries during 2009 could be 64% of annual stewardship fishery removals. Mean lengths of cod sampled at the dock during the 2009 recreational fishery were higher than those sampled at sea in all areas, suggesting widespread discarding of small fish during the 2009 recreational fishery.

The estimate of landings from the 2008 recreational fishery was revised from 818 t to 1089 t using area-specific average weights based on actual sampling of 2008 recreational fishery catches, rather than a provisional average weight of 1.5 kg per fish.

Estimates of commercial catch are also uncertain. Commercial fishers often report that commercial landings are underestimated. If the level is substantial then there is more uncertainty in catch-based assessments and in the evaluation of the impact of future removals.

An estimate is not yet available for the 2009 catch by non-Canadian fleets outside the 200 nautical mile limit on the Nose of the Grand Bank (Div. 3L). The Scientific Council of the Northwest Atlantic Fisheries Organization (NAFO) estimated that annual catch during 2000-2008 were 80 t or less and have been declining.

Landings

Table 1: Reported andings by management year in NAFO Divs 2J3KL (nearest thousand metric tons).

Year	62-76 Avg.	77-91 Avg.	'98	'99	00/ 01	01/ 02	02/ 03	03/ 04	04/ 05	05/ 06	06/ 07[1]	07/ 08[1,2]	08/ 09[1]	09/ 10[1,2]
TAC	N/A	N/A	4	9	7	6	6	0	0	0	-	-	-	-
Can. Fixed	88	90	5	9	5	7	4	1	1	1	3	3	4	3
Can. Mobile	9	84	-	-	-	-	-	-	-	-	-	-	-	-
Others	405	38	-	-	-	-	-	-	-	-	-	-	-	-
Totals	502	212	5	9	5	7	4	1	1	1	3	3	4	3

[1] There was no TAC in the last four years, but fishers were permitted an allowance per license holder of 3,000 lb in 2006/07, 2,500 lb in 2007/08, 3,300 lb in 2008/09, and 3,750 lb in 2009/10.

[2] Does not include estimates of Canadian recreational fisheries.

Species Biology

Cod off Labrador and eastern Newfoundland grow slowly compared with individuals in the eastern Atlantic and further south in the western Atlantic. Since the late 1980s females have been maturing at about age 5, which is younger than in previous years.

Historically much of the stock was highly migratory. They over-wintered near the edge of the continental shelf and migrated in spring/summer to shallow waters along the coast and onto the plateau of Grand Bank.

Small cod tend to feed on small crustaceans; medium-sized cod feed on larger crustaceans and small fish; and large cod feed on medium-sized fish and crabs. Capelin in particular has historically been an important part of the annual diet. Very small cod are eaten by squid, many species of groundfish, including larger cod, and some species of birds. Larger juveniles are eaten by larger groundfish, seals and other marine mammals. Large cod probably have few natural predators, but seals can prey upon them by belly-feeding.

Stock Structure

There is evidence that there are cod populations in the inshore that are functionally distinct from those in the offshore. Inshore populations are small relative to the populations that historically migrated into the inshore from the offshore during spring/summer.

Tagging studies revealed that during the late 1990s to the mid 2000s the inshore of 3KL was inhabited by at least two groups of cod: (1) a resident coastal group that inhabited an area from eastern Trinity Bay northward to western Notre Dame Bay (Fig. 3) and (2) a migrant group that over-wintered in inshore and offshore areas of 3Ps, moved into southern 3L during late spring and summer, and returned to 3Ps in the autumn. Tagging studies also indicated considerable movement of cod among Trinity Bay, Bonavista Bay and Notre Dame Bay.

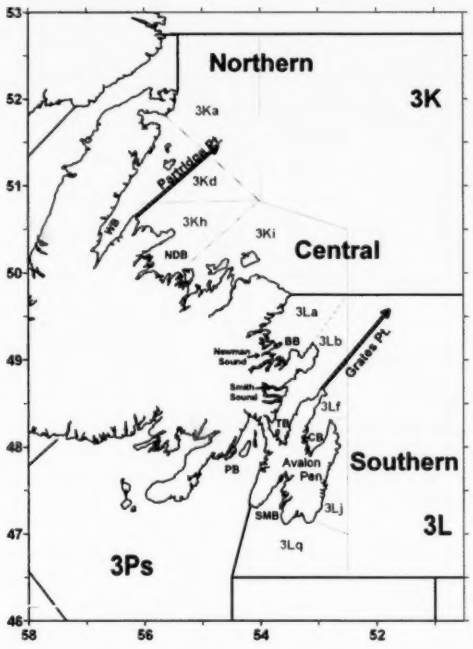


Figure 3: Eastern Newfoundland indicating the locations of the inshore northern, inshore central and inshore southern areas. The northern area extends northward to include 2J (not shown). Major bays are indicated: White Bay (WB), Notre Dame Bay (NDB), Bonavista Bay (BB), Trinity Bay (TB), Conception Bay (CB), and St. Mary's Bay (SMB); Placentia Bay (PB) is in Subdiv. 3Ps. Grey lines delimit boundaries of inshore statistical unit areas (i.e. 3Ka, 3Kd, etc.) referred to in the text.

Some aspects of current stock structure require further study. Catch rates increased in sentinel surveys in 2J and northern 3K in 2005 (see below), but the origin of the fish that generated these higher catch rates is uncertain. The extent of migration between the inshore and offshore of 2J3KL during recent years is not well understood, but new tagging results indicate that the historical shoreward seasonal migration pattern of the pre-moratorium period did occur during 2008 and 2009. The offshore biomass of cod in 2J3KL is low but increased during 2003-2008; the contribution of offshore cod to the inshore biomass during summer may have increased during this period.

Ecosystem information

During the late 1980s and early 1990s the fish community in the Newfoundland and Labrador large marine ecosystem collapsed. This collapse was more dramatic in the northern regions and involved commercial and non-commercial species. During 2002/03 to 2008 there was an increasing trend in the fish biomass in 2J3K and 3LNO; some components of the fish community (e.g. piscivores such as Atlantic cod, turbot, and Atlantic halibut) and large benthivores (e.g. American plaice) showed some positive signals, but still remain at a significantly lower level in comparison to the pre-collapse period. These were the first significant changes observed in ecosystem structure since the collapse. However, the most recent ecosystem information is less optimistic and trends in components of the fish community in 2009 are more variable.

Oceanography

The marine environment off Labrador and eastern Newfoundland experienced considerable variability since the start of standardized measurements in the mid-1940s. A general warming phase reached its maximum by the mid-1960s. Beginning in the early 1970s there was a general downward trend in ocean temperatures, with particularly cold periods in the early 1970s, early to mid-1980s and early 1990s. Ocean temperatures have been above normal for the past decade, with 2006 at a record high, but temperatures in 2007-2009 declined to near normal values.

It is anticipated that cod in this area may be more productive when water temperatures are toward the warm end of the regional norm. Cod somatic growth was showing an increasing trend in 3KL when temperatures were approaching the peak of 2006, but this trend has reversed.

Predators

Summary information from the second workshop to review the impacts of seals on Atlantic cod stocks in eastern Canadian waters indicated an increase in the amount of cod consumed by harp seals since the late 1980s due, primarily, to increased occurrence of Atlantic cod in near shore diet samples. Estimates of total Atlantic cod consumption by harp seals are imprecise. Analyses presented in 2001 indicated that harp seals may have an impact on the recovery of 2J3KL cod; however, ongoing analysis from a simple biomass based model exploring the impact of harp seals on cod under a wide range of consumption estimates suggests that seal predation is not a significant factor in the lack of recovery to date.

Hooded seals and cetaceans are also found in significant numbers in the 2J3KL stock area; diet studies indicate that cod are eaten by hooded seals and some cetacean species but their impacts are not known.

White hake (*Urophycis tenuis*) have been identified as an important predator of cod < 1yr old in the nearshore environment.

Prey

An index of offshore capelin biomass, based on a spring 3L hydro-acoustic survey, indicates that capelin biomass was high in the 1980s, but dropped dramatically in the early 1990s and remained low for several years. There was an increase in capelin biomass offshore in 2007, but the index has subsequently remained unchanged. In the inshore, indices of capelin biomass did not show such extensive declines in the early 1990's; inshore indices are no longer available. Overall, the status of capelin appears to have improved then stabilized; the timing of improvement coincides with the recent increases observed in biomass of cod in portions of the offshore. Capelin arrived inshore later in 2009 than 2008 and were smaller.

ASSESSMENT

In this assessment, a cohort analysis (Cook 1997) of autumn research vessel catch rate data was used to infer trends in the status of cod in the offshore. For inshore and offshore areas, trends in indices and harvest rates inferred from tagging studies were also examined. Catch rates of ages 3 and 4 from sentinel surveys were modeled to develop a recruitment index. Total landings are uncertain and catch-based analytical models such as sequential population

analysis (SPA) could not be used.

Due to differences in the dynamics of offshore and inshore populations since the mid-1990s, information is provided for the offshore and inshore separately.

Sources of information

The main sources of data for this assessment are as follows: For the offshore, indices of abundance, biomass and other biological characteristics are obtained from multi-species research vessel (RV) bottom-trawl surveys conducted by Fisheries and Oceans Canada (DFO) in the whole of Div. 2J3KL during the autumn and in Div. 3L during the spring. Information on recruitment and total mortality is obtained from analysis of catch rate at age in the autumn surveys. Recaptures of conventionally tagged cod and detections of acoustically tagged cod released offshore in February-March 2007 and March 2008 were used to estimate exploitation rates and investigate migration patterns.

For the inshore, indices of abundance are provided by DFO-Industry fixed-gear sentinel surveys, which are conducted by two traditional gears, gillnets of 5½ inch mesh and line-trawls, and a non-traditional 3¼ inch mesh gillnet, which is intended to provide information on young fish. Logbooks from vessels less than 35 feet for post-moratorium fisheries were also examined to investigate area-specific trends in catch rates. Tagging studies initiated in 1997 and continued during 2006-2009 provide information on exploitation, distribution and migration. Hydro-acoustic surveys (Rose 2003) were conducted in Smith Sound in winter and spring 1997-2004 and 2006-2009. An annual telephone survey of fish harvesters' observations is conducted by the Fish, Food and Allied Workers (FFAW) Union. Information on the relative abundance of young cod (Ages 0 and 1) is provided by beach seine studies in Newman Sound, Bonavista Bay (Fig 3). Information on the size and age composition of the catch is obtained from lengths and otoliths collected from cod sampled at ports and at sea. A DFO-Industry bottom-trawl survey using small (<65 ft) commercial vessels was conducted annually during July-August 2006-2009. This inshore trawl survey provides information on the relative abundance, age composition and distribution of cod inhabiting the coastal and nearshore area of 2J3KL.

Oceanographic information and trends in key predators and prey were examined, and broad ecosystem trends were reviewed.

Stock Trends – Offshore

Bottom-trawl surveys

The abundance and biomass indices from the autumn RV surveys during 2006-2008 are both 9% of the average during the 1980s. The abundance index has been increasing since 2003; the biomass index increased during 2003-2008, but the 2009 value is marginally lower (Figs. 4, 5).

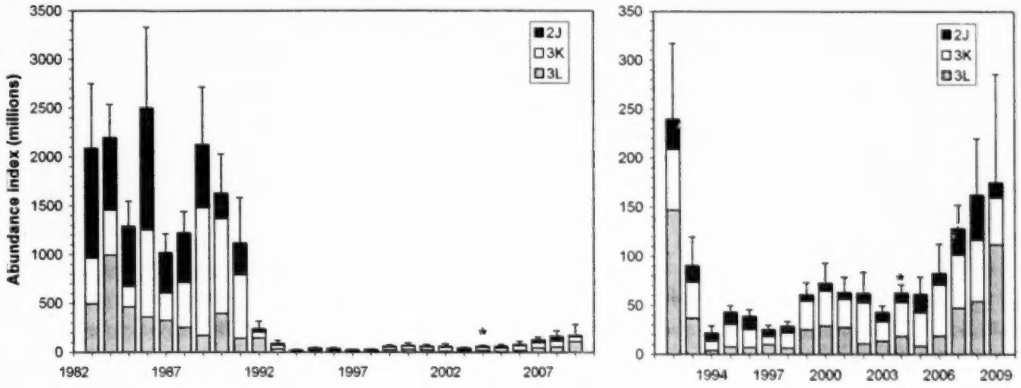


Figure 4: Offshore abundance index (+2 SE's) from autumn RV surveys in 2J3KL. The right panel is expanded to show trends from 1992 onwards. Asterisks indicate partial estimates from incomplete survey coverage of 3L in 2004.

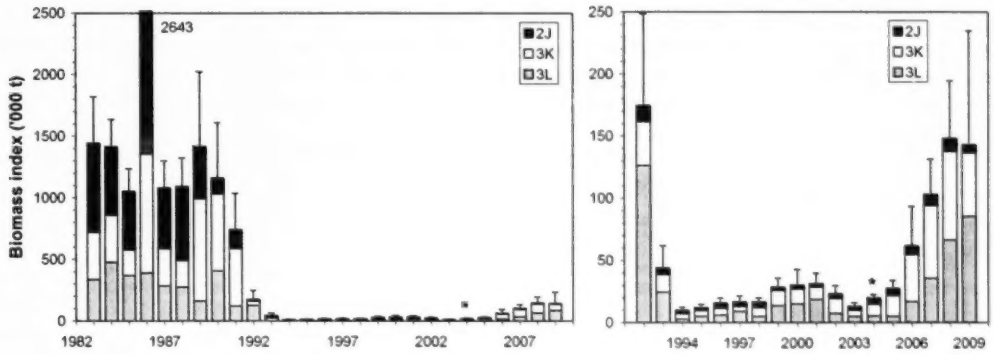


Figure 5: Offshore biomass index (+2 SE's) from autumn RV surveys in 2J3KL. The right panel is expanded to show trends from 1992 onwards. Asterisks indicate partial estimates from incomplete survey coverage of 3L in 2004.

The 2009 survey abundance index and biomass index values are 175 million and 143,000 t. The autumn 2009 offshore RV survey abundance and biomass is concentrated (32% and 64% of totals, respectively) adjacent to the 3K/3L boundary. This region encompasses only 14% of the total surveyed offshore area of 2J3KL, and in the 1980's contained <20% of survey abundance and biomass. There has been little increase in biomass in 2J.

In 2004, the autumn survey did not complete a portion of northeastern 3L that includes seven strata where cod have often been found at higher density in previous surveys. The survey estimate for 2004 is probably low.

The spawning stock biomass (SSB) index from the fall RV survey during 2007-2009 was 10% of the average in the 1980s (Fig. 6). The SSB index from this survey increased during 2005-2008, but the 2009 value (76,000 t) was 29% lower than in 2008.

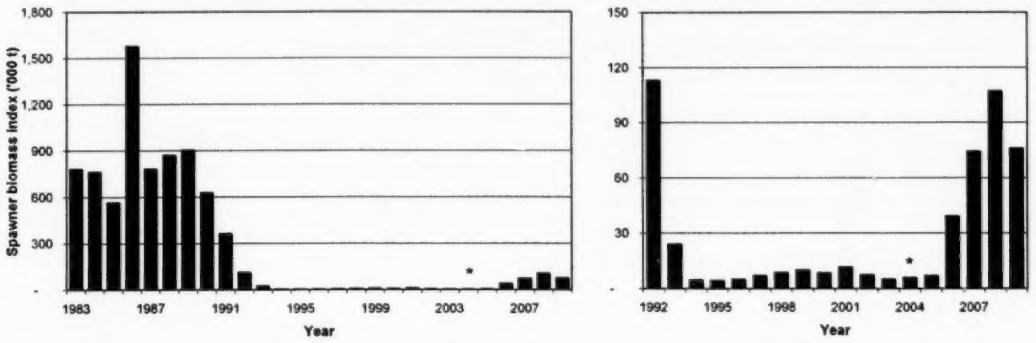


Figure 6: Offshore spawning stock biomass index from autumn RV surveys in 2J3KL. The right panel is expanded to show trends from 1992 onwards. Asterisks indicate partial estimates from incomplete survey coverage of 3L in 2004.

Information on recruitment and mortality is derived from mean catch rate at age during the autumn RV surveys.

Year-class strength in the offshore in the 1990s and 2000s has been poor compared to the 1980s. The number of young fish (ages 2 and 3) in the offshore survey in the 1990s and 2000s has consistently been much lower than during the 1980s (Fig. 7).

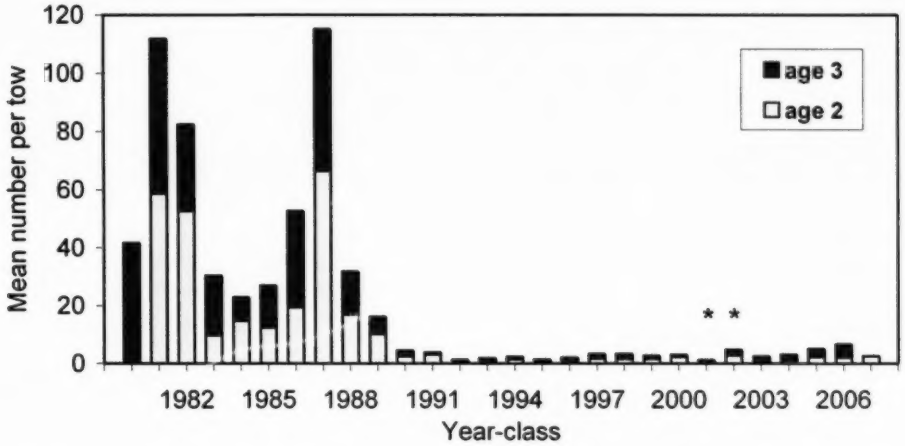


Figure 7: Abundance of the 1980-2007 year-classes at age 2 and age 3 in the offshore of 2J3KL from the autumn RV surveys. Asterisks indicate partial estimates for the 2002 year-class at age 2 and the 2001 year-class at age 3 due to incomplete survey coverage of 3L in 2004.

The total mortality rate (ages 4-6) remained at a high level throughout the mid-1990s, and increased further during 2001-2003 (Fig. 8); this high level of mortality has been a major impediment to stock recovery. Total mortality has declined substantially since 2003 and this has been an important factor in the recent increase in total biomass and SSB. The lack of older fish (ages 8 and older) in the survey since the early 1990s is a consequence of the high rate of mortality; however, in the last few years the age composition has been expanding. The total mortality rate in 2007-2009 averaged 0.28, which corresponds to 24% mortality per year. The total mortality rate during 1996-2009 averaged 0.79, which corresponds to 46% mortality per year.

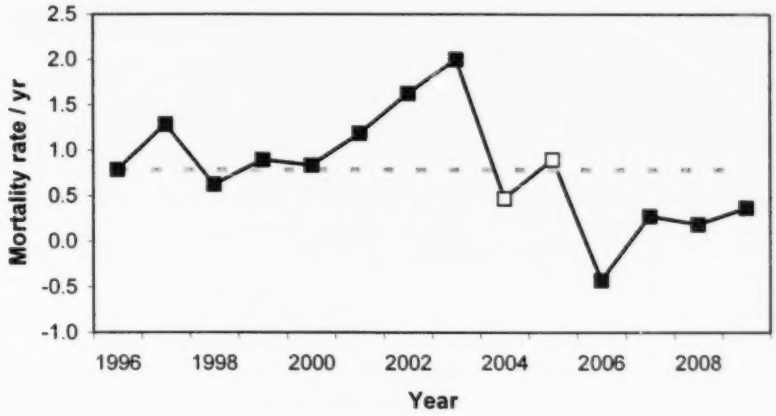


Figure 8: Total mortality rate (Z) of cod aged 4-6 calculated using data from the autumn RV surveys in the offshore of 2J3KL. For example, the value in 1996 is the mortality experienced by the 1991-1989 year-classes from ages 4-6 in 1995 to ages 5-7 in 1996. The dashed line is the time-series average. Open symbols indicate estimates based on an incomplete survey in 2004.

Total mortality rate is lower in the past 3 years in spite of re-opening of the inshore fishery (in 2006), suggesting that natural mortality rates have declined substantially.

A cohort analysis (Cook, 1997) of the DFO autumn survey RV data (ages 2-8, 1995-2009, excluding 2004) indicated that total biomass has increased (23% per year) since 2004 (Fig 9). Spawning stock biomass increased (83% per year) from 2004 to 2008, but the 2009 value was similar to 2008 (Fig 9). The 2004 RV survey was excluded in this analysis due to incomplete survey coverage.

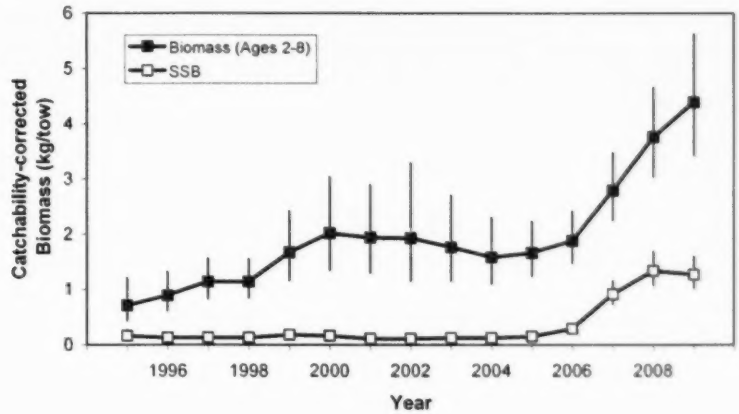


Figure 9. Trends in biomass (ages 2-8) and SSB estimated from cohort analysis of DFO survey data. Error bars are 95% confidence intervals.

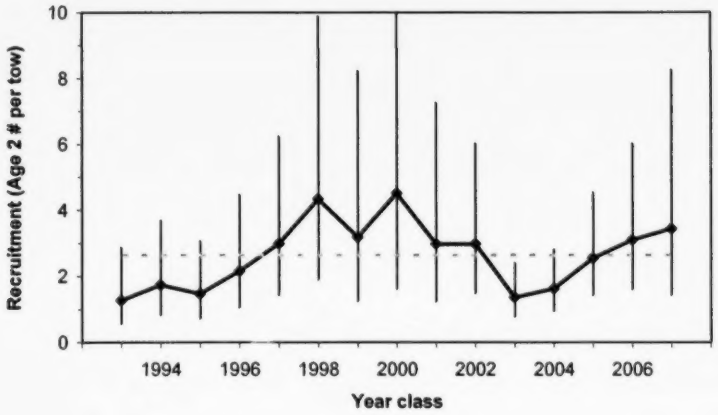


Figure 10. Trends in recruitment (age 2) from cohort analysis of DFO survey data. Error bars are 95% confidence intervals.

Cohort analysis indicates that the relative strength of the 1998-2002 year-classes are all above the 1993-2007 average, whereas the 1993-1996 and 2003-2004 year-classes are below average (Fig. 10). The strength of the most recent year classes is based on few data.

The recent increases in offshore biomass and SSB were mostly due to improved survival and growth of the 1998-2002 year-classes. The 2003 and 2004 year-classes are weaker and these have now entered the SSB; consequently, the recent rate of stock growth is unlikely to continue in the short term. The lack of increase in SSB in 2009 may be reflecting the influence of these weaker year classes. Subsequent year classes (2005 and 2006) are estimated at about the 1993-2006 average.

Estimates of the total mortality rate (Z) from the cohort analysis (ages 4-8) indicate that the total mortality was high (~1.0) during 1995-1999, increased further to 1.5 during 2002, but declined substantially during 2003-2006 (Fig. 11). The average value for 2007-2009 is 0.42 which corresponds to 35% mortality per year.

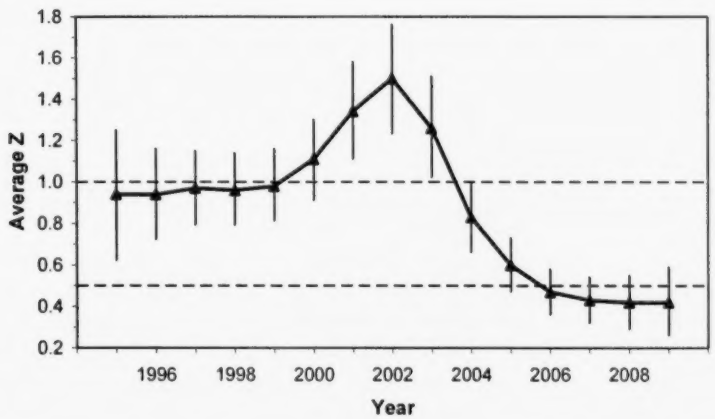


Figure 11: Total mortality rate (Z) of cod aged 4-8 estimated from cohort analysis of DFO survey data. The dashed lines indicate values of Z=1.0 and Z=0.5 which correspond to annual mortality rates of 63% and 39%, respectively. Error bars are 95% confidence intervals.

Biological Information (Offshore)

The information in this section comes from sampling during the autumn offshore RV surveys.

Growth

Length-at-age and weight-at-age have improved since the low values of the early 1990s and were close to average in 2J, but above average in 3K and 3L. In 2009, growth remains close to average in 2J, but has declined to average in 3K and below average in 3L.

Condition

Condition of cod, as measured by both gutted weight (relative condition) and liver weight (relative liver condition), are lower in Div 2J, but higher in 3K and 3L compared to the early 1980s. However, both measures of condition declined in 2009. Relative liver condition in 2009 declined substantially from 2008.

Maturity

The proportion of female cod that are mature at young ages has increased over time particularly among cohorts produced from the late 1980s onward. For example, the percentage of age 6 cod that are mature averaged about 50% in the 1980's, but has increased to about 80% since the early 1990s. Values for age at maturity among recent cohorts (2002-2005) show a slight trend towards maturation at older ages, but the most recent values are more uncertain. Males generally mature about one year younger than females and show a similar trend over time. The reasons for the change towards earlier age at maturity are not fully understood. The change may have a genetic component and partly be associated with high levels of mortality and low stock size.

The most recent information on cod growth rates and condition indicate that these aspects of stock productivity have declined in the past 1-2 years; age at maturation also remains low. These components of stock productivity are below the levels observed in the 1980s when biomass and harvests were much larger.

Offshore tagging

Offshore cod were captured and released with conventional and acoustic tags in deep water (> 330 m) on the outer edge of the continental shelf in Div. 3K during February-March 2007 and March 2008.

In the summer and fall of 2007-2009, offshore tagged cod were recaptured inshore in the recreational and stewardship fisheries; recaptures were widely distributed throughout 3K and 3L as far south as Petty Harbour (3Lj) in 2008, whereas inshore recaptures were more clustered in 2009. Offshore cod with acoustic tags were also detected on receiver arrays in nearshore of 3KL during 2008 and 2009, and >25% of those released in 2008 have now been detected inshore. A substantial portion of cod from the offshore migrated to the inshore of 3KL during summer 2008 and 2009, rendering them vulnerable to inshore fisheries. The estimated exploitation rate of offshore cod in the inshore based on tag returns was 6% in 2008 and 2% in 2009.

Stock Trends – Inshore

For assessment purposes the inshore was divided into three areas: 1) a northern area (2J and northern 3K); 2) a central area (southern 3K and northern 3L) where most of the resident inshore fish are located; and 3) a southern area (southern 3L) that is largely dependent on migrant fish, from 3Ps and possibly other offshore areas. The dividing lines for these areas are Partridge Point at the western side of Notre Dame Bay and Grates Point at the eastern side of Trinity Bay (Fig. 3).

Stewardship Fishery

Catch and effort data for the < 35 ft. sector from log-books for the 2008 and 2009 stewardship fishery were examined. Median catch rates (in terms of weight) during 2008 were higher than those observed in 2007 in all three areas. However, in 2009, median catch rates were lower in Notre Dame Bay (3Kd, 3Kh, 3Ki) and the eastern Avalon (3Lj), but higher in Bonavista Bay (3La), Trinity Bay (3Lb) and Conception Bay (3Lf)(see Fig 3. for area boundaries).

The stewardship fishery catch has been dominated (in terms of weight) by cod age 5 and 6 during 2006-2007 and this is a typical pattern for a fishery dominated by gillnets. However, there was a substantial decline in cod age 5 (2003 year class) in 2008 and cod aged 5 and age 6 (2004 and 2003 year classes) during 2009. These changes are consistent with the year class strength information from surveys and cohort analysis which indicates that the weaker 2003 and 2004 year classes have moved into the exploitable biomass and SSB.

Sentinel surveys

In the northern area, catch rates with gillnets (5½ inch mesh) were low in 1995-2004, increased in 2005, and are currently above the average of the time series (Fig. 12). In the central area, catch rates have generally increased since 2002 and are currently above average. In the southern area, catch rates have remained stable since 2003 but are marginally below average. In all three regions catch rates were lower in 2009 compared to 2008, suggesting that exploitable biomass was lower.

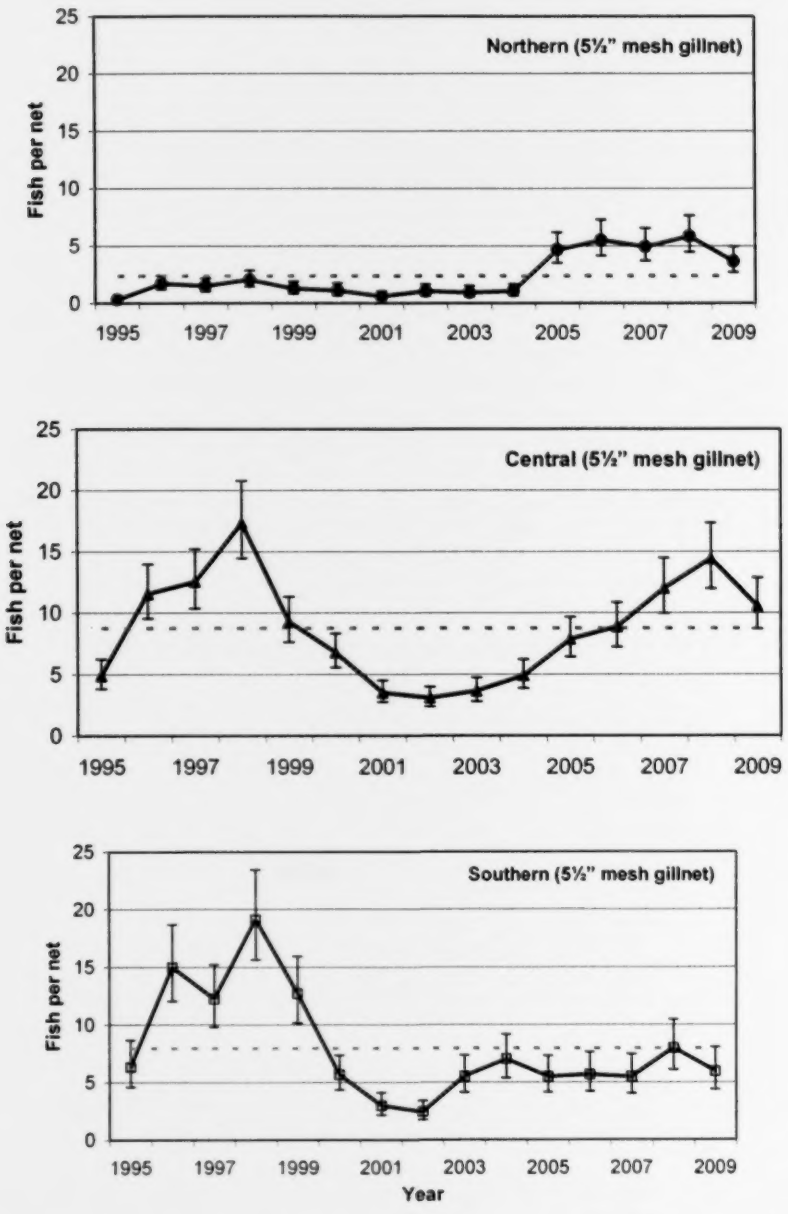


Figure 12: Standardized catch rates, with 95% confidence limits, from sentinel surveys using gillnets (5½ inch mesh) for each of the three inshore areas. Series means are plotted as dashed lines.

In the central area, catch-rate indices from line-trawls have been variable but show an increasing trend since 2002 and are above the average of the time-series (Fig. 13). There are insufficient line-trawl data in the northern and southern areas to produce a standardized index time series.

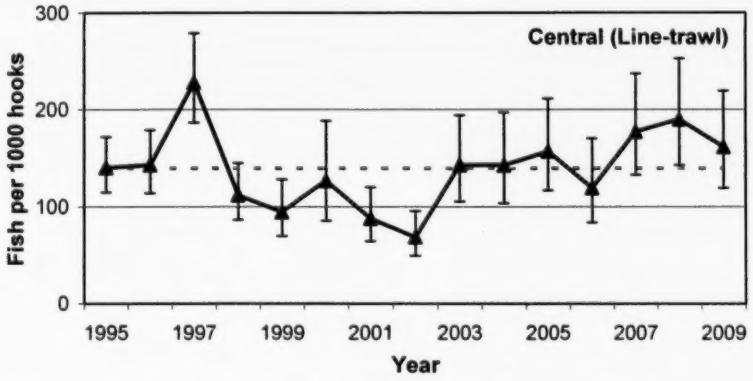


Figure 13: Standardized catch rates, with 95% confidence limits, from sentinel surveys using line-trawls for the inshore central area. Series mean is plotted as a dashed line.

Sentinel survey – recruitment

An inshore recruitment index was derived from catch rates of juvenile cod during the sentinel survey (Fig. 14). The 1992, 2000, and 2002 year-classes are well above the average of 1992-2006. The four most recent year classes are estimated to be average (2004) or weaker than average (2003, 2005, 2006) and these are now contributing to the exploitable biomass. These results are generally consistent with recruitment information from the offshore.

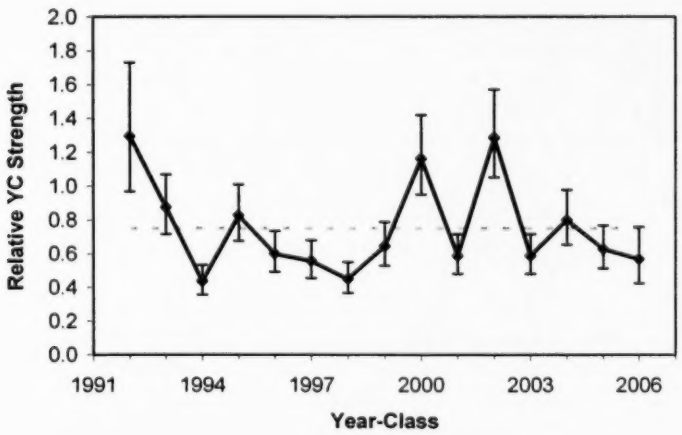


Figure 14: Standardized year class strength from sentinel survey catch rate data for ages 3 and 4 using 5½ inch and small mesh (3¼ inch) gillnets for the inshore central area. The dashed grey line is the time-series average.

Biological Information (Inshore)

The information in this section comes from sampling during the sentinel survey.

Growth

Length-at-age and weight-at-age have been declining since 2006 among younger cod,

particularly those age 3 and age 4 in 3K and in 3L. Length-at-age and weight-at-age among older cod (>age 8) are more variable and show no trend.

Condition

Condition of cod, as measured by gutted weight, has shown a decline in all divisions since 2005 and values in 2009 are among the lowest in the time series (1995-2009). Condition of cod, as measured by liver weight, is consistently lower in Div 2J. Liver weight declined substantially in 3K and 3L from 2008 to 2009 and the most recent values are among the lowest observed.

Beach seine surveys

Information on the strength of recent year-classes is available from a beach seine survey in Newman Sound, Bonavista Bay (northern 3L). This survey catches cod mainly of ages 0 and 1, with age 0 being much more strongly represented. These pre-recruit ages are not adequately represented in other indices. The information on age 1 from this study has been consistent with the sentinel indices for the same year-classes at older ages. Several year-classes (2003-2006, 2008) are weak at age 1 and the 2005 year-class is the lowest in the time-series (Fig. 15); however, the 2007 year class at age 1 is close to the average for year-classes produced during 1995-2007.

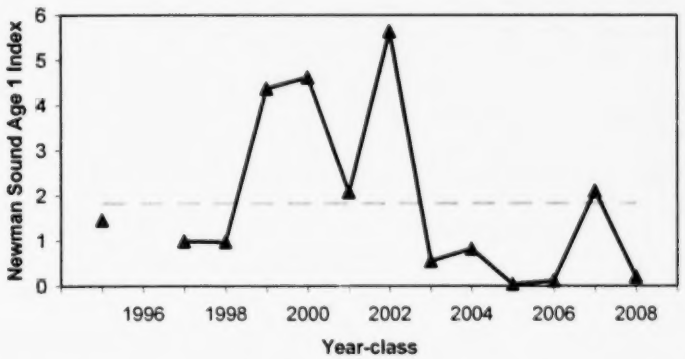


Figure 15: Trends in the numbers of age 1 cod from beach seine surveys in Newman Sound. Series mean is plotted as dashed line.

Numbers of age 0 cod caught at Newman Sound and several other sites during 2009 surveys were lower than average. However, survival to age 1 can be highly variable; therefore, the strength of the 2009 year-class is currently uncertain.

Hydroacoustic surveys

Winter hydroacoustic studies were conducted in Smith Sound in western Trinity Bay (Fig. 2) starting in 1999 (Rose, 2003). Biomass indices increased to a peak of about 26,000 t in 2001 and then declined to 18,000 t in 2004. The surveys were suspended in 2005 but resumed in 2006. Biomass indices were stable in 2006 at 16,500-18,500 t, but declined to 14,000 t in 2007 and to 7,200 t in 2008, the lowest in the time series. The estimated biomass from a survey conducted in 1-3 April 2009 was 600 t. However, it is uncertain whether the 2009 results are representative of over-wintering biomass in 2009 as most surveys in previous years were conducted earlier (January-March). Low exploitation rates from conventional tagging and high survival rates of acoustically tagged cod suggest the decline is not solely due to the combined

effects of fishing and natural mortality. The decline more likely reflects a redistribution of some over-wintering cod to other inshore areas or to the offshore.

DFO-Industry bottom-trawl survey

This survey was conducted in July-August from 2006-2009 and covered nearshore areas from 15 m to 200 m depth. Catches have consistently been higher in the coastal strata (< 50 m depth in particular) and lowest in the northern area from 2006-2009. The time series is still too short to interpret trends in catch rates, but results demonstrate high variability with the central and southern areas influenced by large sets in some years. Typically ages 1-3 have comprised most of the survey catches (>65% by number) but a different pattern was evident in 2009 with the central area exhibiting a broader range of ages from 1-8. The 2008 and 2009 survey results indicate a prominent 2007 year class in both central and southern areas. Survey estimates of this year class were greatly reduced during 2009.

Inshore tagging

Information from recaptures of cod tagged in various inshore regions of 3KL during 1997-2009 was used to estimate average annual exploitation (harvest) rates.

During 2006, when the stewardship fishery opened, exploitation rate estimates increased to 10% for the inshore central area where the reported landings were 1,750 t; the exploitation rate was much higher in southern 3K (20%) than in Bonavista Bay and Trinity Bay combined (7%). In 2007-2009, exploitation rates were consistently low among central and southern areas, ranging from 5-10% in 2007, 6–7% in 2008 and from 3-9% in 2009. These estimates included a range of assumptions about natural mortality (0.1- 0.4).

The reporting rate of tags from commercial fishers declined slightly during 2006-2009 (57-64%) compared with previous years (1997-2005, 68-90%) indicating that fishers are becoming less inclined to return tags and recapture information. A constant but lower reporting rate of tags was estimated for recreational fishers during 2006-2009 (46-50%). Lower reporting rates add uncertainty to the estimates of exploitation rates, and analyses of movement patterns and stock structure.

Sources of Uncertainty

The relative proportions of inshore versus offshore cod that contribute to the inshore fishery catches is uncertain. However, the proportion of offshore cod is likely to have increased compared to the mid-1990s and early 2000s.

Some of the autumn RV surveys have extended well beyond their normal time and into the winter because of vessel problems (Brodie and Stansbury 2007). In addition, the survey was not fully completed in some years and coverage in some regions was sparse. These changes add uncertainty to survey estimates of mortality rates, abundance, and biomass.

Estimates of stewardship fishery catch are also uncertain. At stock assessment meetings and consultations commercial fishers often report that stewardship landings and recreational removals are underestimated. If the level is substantial, then there is more uncertainty in catch-based assessments and in the evaluation of the impact of future removals.

There are no direct estimates of recreational landings for 2009. Estimates of removals from recreational fisheries in other years are uncertain. Without accurate estimates of recreational catch, total catch for northern cod remains uncertain.

There is uncertainty in the survival of fish caught in deep water (>300 m) offshore and released after tagging and implantation of acoustic tags. Ongoing research indicates that post-release mortality of cod trawled from deep water is variable but can be substantial.

INDUSTRY PERSPECTIVE

2009 fishery

In contrast to the recreational fishery, the stewardship fishery for cod (as prosecuted by commercial fish harvesters) is a limited entry fishery with gear restrictions (amount and type of gear), seasonal and duration restrictions, and landings are closely monitored at sea and at dockside. The data collected by commercial fish harvesters, during their participation in this fishery is very important to the continued monitoring of the recovery of this stock (inshore and offshore).

Fish harvesters feel that while the high catch rates during the late 1990's were largely driven by a narrow band of cod aggregations close to shore, much has changed in recent years. While current catch rates are about the same as those of the late 1990's cod are much more widely distributed over inshore and offshore fishing grounds in very shallow depths to depths of 150 fathoms. Harvesters feel that the current level of abundance combined with the current distribution and migration patterns that resemble historical patterns is evidence that a significant recovery has and is taking place. Based on observations of the range of year-classes and the level of abundance, harvesters feel that the current allowance can be increased and recovery can continue to take place.

Telephone survey of fish harvesters

Two hundred and eighty two 2J3KL fish harvesters participated in a telephone questionnaire conducted by the FFAW in February 2010. Most harvesters felt that cod were more abundant during 2009 than during the 1980's. Most 3K and 3L harvesters felt cod abundance was better in 2009 than in the late 1980's. Harvesters in 2J3KL found cod abundance in 2009 comparable or the same as 2008. Most harvesters felt that cod were distributed throughout their area and felt that condition and the health of cod were good. The majority of fish harvesters in all areas felt capelin, mackerel and squid abundance is at a low level and declining.

CONCLUSIONS AND ADVICE

Conclusions are presented for offshore and inshore separately, and advice is provided for the stock as a whole.

Catch

Total catch in 2009 is uncertain. Accurate catch information is needed to evaluate the impact of future fishery removals on stock growth.

Reported landings in 2009 were 3,098 t. This included 2,832 t in the stewardship fishery, 216 t in the sentinel surveys, and 50 t taken as by-catch, but excludes recreational fishery removals.

There are no direct estimates of recreational landings for 2009. However, analysis of tag returns suggests that removals from recreational fisheries during 2009 could be 64% of the stewardship fishery removals. Also, mean lengths of cod sampled at the dock during the 2009 recreational fishery were higher than those sampled at sea in all areas, suggesting widespread discarding of small fish during the 2009 recreational fishery.

Offshore

Based on a cohort analysis of the autumn DFO research vessel (RV) trawl survey, total **biomass** has increased (23% per year) since 2004. **Spawning stock biomass (SSB)** increased (83% per year) from 2004 to 2008, but the 2009 value was similar to 2008.

Total **mortality** in the offshore was extremely high during 1996-2003 and was a major impediment to stock recovery. Total **mortality** has declined substantially since 2003 and this has been an important factor in the recent increase in total **biomass** and **SSB**.

The 2003 and 2004 year-classes are weaker than those produced in 1998-2002 and have now entered the **SSB**; this is why **SSB** did not increase in 2009. Consequently, the rate of stock growth during 2004-2008 is unlikely to continue in the short term. Subsequent year classes (2005 and 2006) are estimated at about the 1993-2007 average.

The average survey **SSB** estimate in the offshore over the last 3 years is 10% of the average during the 1980's and is concentrated adjacent to the 3K/3L border. This is directly eastward of the central inshore area where stewardship fishery and sentinel catch rates are highest. There are still large portions of the offshore area where cod are at low abundance relative to the past.

The number of young fish (ages 2 and 3) in the offshore survey in the 1990s and 2000s has been consistently much lower than during the 1980s. Further stock growth will require an improvement in recruitment, and the increase in **SSB** (2004-2008) has not yet resulted in stronger year-classes.

Offshore tagging and telemetry indicate that a substantial portion of cod from an offshore aggregation migrated to the inshore of 3KL during the summer, similar to historic patterns. Exploitation of these offshore cod in the inshore was low, estimated at 6% in 2008 and 2% in 2009.

Inshore

Sentinel catch rates suggest that **exploitable biomass** in 2009 was near the 1995-2009 average, but lower than in 2008 for the northern, central and southern inshore regions.

In the inshore northern area catch rates are lower than those in the central area suggesting lower **exploitable biomass** in the northern area. Fisheries in this area depend on seasonal immigration of fish, possibly from offshore regions, including 2J where offshore biomass remains low. There is little evidence of immigration of cod from offshore 3K or the inshore central area. Therefore, it is recommended that removals from this area be minimized.

During 2007-2009, mean exploitation rates from tagging studies were low and ranged from 3-10% among inshore central and southern areas. These estimates included a range of assumptions about natural mortality (0.1- 0.4).

In the inshore central area, catches depend on resident inshore components and seasonal migrants from the offshore. The contribution of offshore cod to catches in the inshore central area is thought to be increasing, but exploitation remains low.

Exploitable biomass in the central inshore area is likely to decrease further in 2010 even with no removals. The 2003 and 2004 year-classes are weaker than those produced in 2000 and 2002, and the 2002 year-class is moving out of the exploitable biomass. Therefore, if current levels of removals are maintained then exploitation rates in the central inshore area are expected to increase in 2010.

In the inshore southern area, catches are partly dependent on seasonal immigration of fish from the offshore of 3KL, and from 3Ps where the stock is declining.

The 2009 industry telephone survey showed most harvesters in 2J3KL felt that cod were more abundant during 2009 than in the 1980s.

Whole stock

In recent assessments, information from inshore and offshore components have been analysed separately. Overall, the offshore components now represent most of the stock.

Although a specific limit reference point has not been established, the stock is clearly below any reasonable value. The application of the precautionary approach would require catches in 2010 to be at the lowest possible level. This would include no directed fishing and measures to reduce cod by-catch in other fisheries.

Current levels of removals have resulted in low exploitation rates and probably have had little impact on recent stock dynamics. In general, the 2003-2005 year-classes are weaker than those from 1999-2002. Consequently, even with no fishing, the recent (2004-2008) high rate of growth in **SSB** is unlikely to continue in 2010. Current levels of removals will not greatly affect the rate of change in **SSB** in 2010.

OTHER CONSIDERATIONS

Management Issues

Recreational fishery

At current levels of removals, the recreational fishery is a substantial component of total removals. Improving the management of recreational fisheries is strongly recommended so that total removals can be effectively controlled and directly measured, and more accurate catch information provided to science to evaluate the impacts of fishing.

Consequences of an inshore fishery

Cod currently offshore in 2J3KL have now been shown to undergo spring/summer feeding migrations to the inshore during 2008 and 2009, similar to their historic pattern. The moratorium

in the offshore is therefore no longer sufficient to protect the offshore stock until recovery is well established. At current levels of exploitation and natural mortality, the risk that fishing inshore will have a major impact on stock growth offshore seems low; but it is advised that exploitation rates inshore should not be allowed to increase.

Managers should be aware that the year classes that have supported recent fisheries have mostly moved out of the exploitable biomass and have being replaced by two weaker year-classes (2003 and 2004). Consequently, exploitable biomass in the inshore is likely to decrease further in 2010 even with no removals. If current levels of removals are maintained then exploitation rates are expected to increase.

Implications of fishing bay-by-bay

The distribution of fish harvesters is not uniform and does not match the distribution of cod. In some years this has caused geographic variability in fishing mortality rates, as evidenced by tagging studies. Therefore, fishing bay-by-bay may result in local over-exploitation, particularly in areas such as 3Ki, where resident inshore cod are less abundant and effort is high. In addition, some areas such as 2J depend on seasonal immigration of fish, possibly from offshore regions, including the offshore of 2J where biomass remains low. Managers are advised to keep exploitation rates low on all components. This will encourage further rebuilding and preserve and enhance population spatial structure and diversity within the stock.

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FOR MORE INFORMATION

Contact: John Brattey
Fisheries and Oceans Canada
PO Box 5667
St. John's, NL A1C 5X1
Tel: (709) 772-2001
Fax: (709) 772-4105
E-Mail: john.brattey@dfo-mpo.gc.ca

This report is available from the:

Centre for Science Advice
Fisheries and Oceans Canada
Newfoundland and Labrador Region
PO Box 5667
St. John's, NL A1C 5X1

Telephone: (709) 772-3688
Fax: (709) 772-5315
E-Mail: nadine.templeman@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas

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